DEPARTMENT
OF THE
ENVIRONMENT

GENERAL INFORMATION LEAFLET 25

Passive solar house designs

– the Farrans study

- Achieving a compact building and minimising heat loss should be top priorities
- Simple measures such as reducing north-facing glazing are the most likely to succeed
- Compact form is more important than modifying internal layout and window disposition
- Passive solar design is easily understood and can be readily applied

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INTRODUCTION

Passive solar house and site design is popular with house buyers because they like sunny houses and gardens

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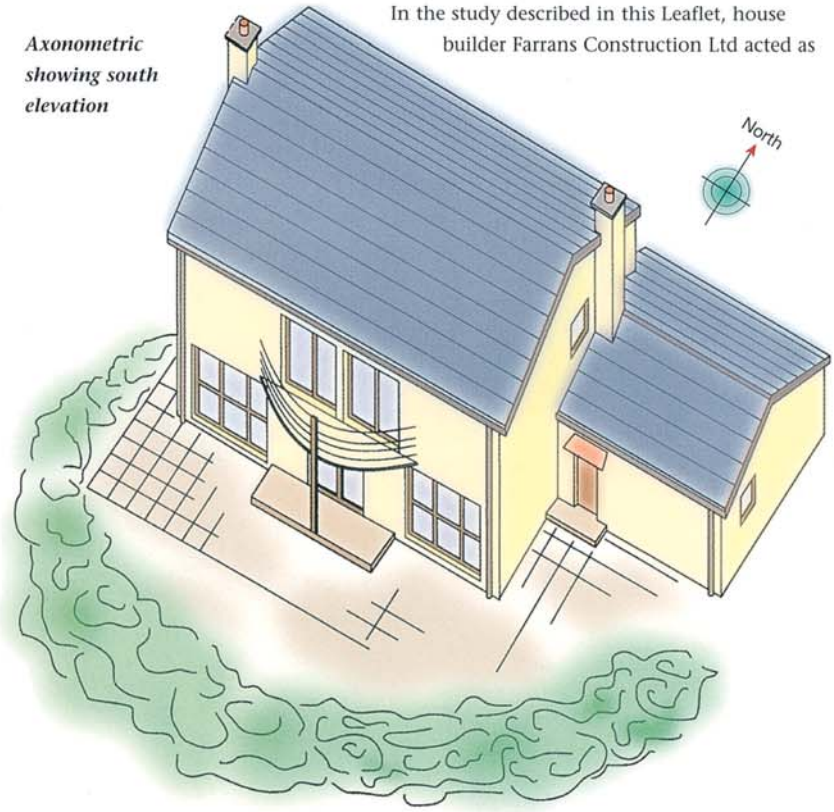
Sunlight through windows is a useful source of energy for houses. It can help to reduce the need for conventional heating, and consequently will reduce the emission of greenhouse gases. Simple design techniques have been developed to exploit this free energy under the general heading of 'passive solar design'. These techniques can be readily integrated with conventional construction and other measures for energy saving, such as improved insulation and better boiler efficiency.

The House Design Studies

As part of its House Design Studies programme the Department of Trade and Industry (DTI) commissioned architects to develop a range of passive house designs. These examples of passive design were then assessed for performance, cost, marketability and amenity. House builders were invited to act as 'quasi-clients' to advise on marketability and practicability.

In the study described in this Leaflet, house builder Farrans Construction Ltd acted as quasi-client for a design by architects Kennedy Fitzgerald and Associates of Belfast.

Axonometric showing south elevation



The design

The architect's task was to design, for a specific site and price, a four-bedroomed detached house with a double garage attached and a heated floor area of 138 m^2. After comments from the client and the energy consultant, the initial design was revised to make it more energy efficient and cost-effective.

SITE DESIGN

Site density

The site is of 1.4 hectares and situated at Drumburg, a village near Belfast. It is a green field site with a slope to the north, surrounded by open space or gardens and therefore presenting minimal problems of overshadowing from outside the site. A study of the site layout investigated how good orientation, with minimal overshadowing, might be achieved for 13 houses. The low site density provided sufficient space within each house plot for the designers to propose a south orientation for the main glazed façade of all the houses.

Orientation of houses

Results from the DTI's House Design Studies confirmed that the main glazed elevation of a house should face within 30° of south if the full energy savings were to be realised. In this study, computer modelling was used to predict the sensitivity of the design to orientation. The results showed that if the main glazed elevation of the houses were to face south-west or south-east (ie 45° of south) the heating demand would increase by 2% and 4% respectively and if it were to face west or east the increase would be 9% and 11% respectively. This sensitivity to orientation is caused by the concentration of glass on the south side.

SITE DESIGN

Site layout

There is a danger of creating a monotonous site layout if all the houses are given a due south orientation. This can be avoided by use of various design techniques such as those illustrated in the Barratt study (see General Information Leaflet 22 'Passive solar house design – Barratt Study' (GIL 22)). In the Farrans study, the designers proposed that excess site soil should be formed into earth berms. Their intention was to create a variety of shapes within the groundscape, firstly to improve the microclimate by reducing near-ground air movement and secondly to increase privacy within the houses. Experience has shown that where householders' privacy is compromised, net curtains are likely to be hung in the windows. This can have the effect of reducing solar gains by about 20%, so defeating the designer's intention.

In the site layout (figure 1) access to each house is shown coming from either the north or the south. This Leaflet illustrates the house type designed for entry from the north only, but a variant was also designed for south entry.

Avoiding overshadowing

The low density and the absence of obstructions around the site limited the extent to which solar gains would be reduced by overshadowing. The design was also given a low pitched roof which helps to minimise overshadowing. The computer modelling showed that the heating demand would be reduced by 10% if the overshadowing angle were to be decreased from 15° to 5° by spacing the houses further apart.

Effect of geographical location

The study also looked at the effect of latitude on energy use by comparing the predicted energy use in Belfast with that on a similar site in London and Glasgow. Compared with Belfast, the house in London would use 15% less energy and in Glasgow 1% more energy. In all these locations, solar gains are predicted to provide 32% of the gross energy, but in terms of actual solar energy supplied in kilowatt-hours, the solar gains are greater at the higher latitudes. This is because vertical glazing presents a greater solar aperture to the sun, which is at a lower angle in northern latitudes.

INITIAL DESIGN

The architect's principal design strategy was to rely on direct solar gain and to minimise heat losses. The first design was revised after comments from the client and the energy and cost consultants. The main changes involved moving the two largest of the four bedrooms from the north to the south side of the house to make better use of solar gains; removal of a tiny 'conservatory/sunspace' which added to cost without being large enough to be of practical use, and which was in any case ineffective as an energy saving measure; and changing the specification of the glass from low-emissivity double glazing to standard double glazing which saved £1470 at 1992 prices. Further cost savings were also made by reducing the number of window types.

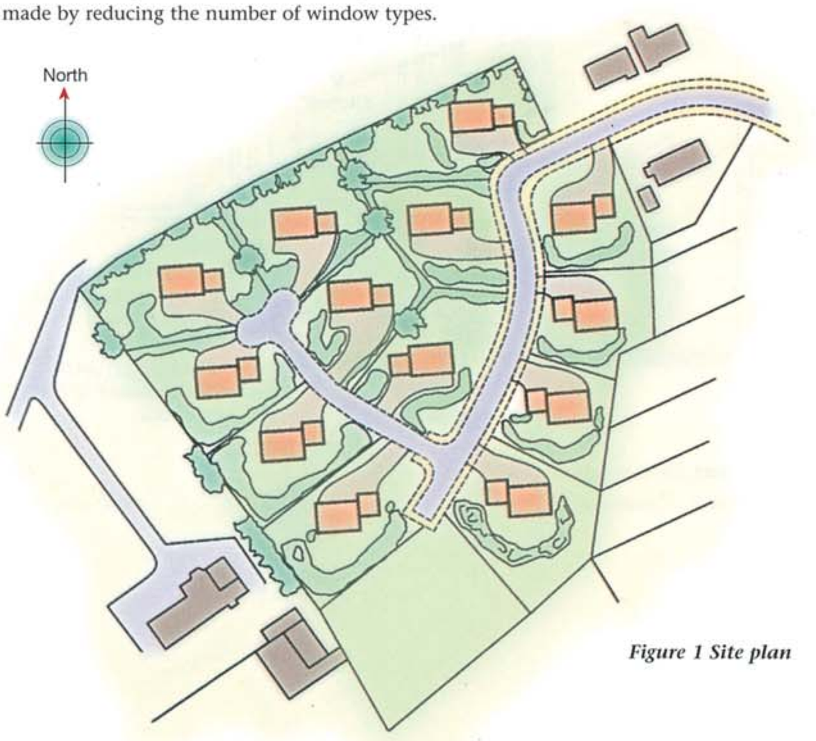
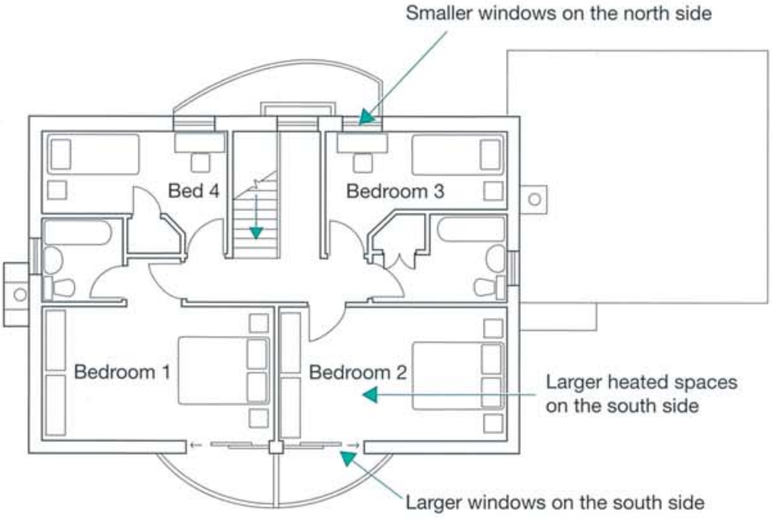
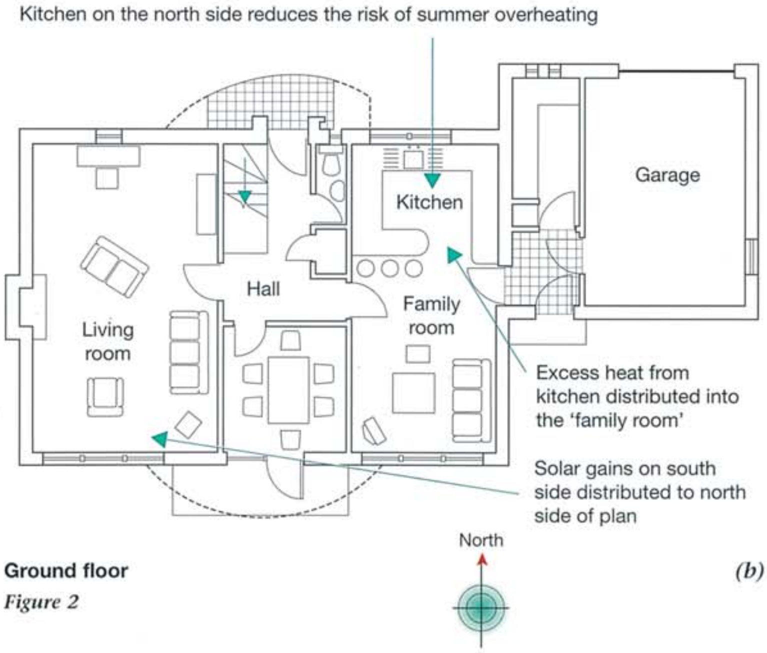


Figure 1 Site plan

FINAL DESIGN



First floor *(a)*



Ground floor *(b)*

Figure 2

FINAL DESIGN

The final design is a traditional two-storey house of brick/block cavity wall construction which relies on the following straightforward but cost-effective low energy design measures.

- ***Careful site planning and orientation;*** southerly orientation with low pitched roofs and layout of houses to minimise overshadowing, and landscaping to reduce wind speed.
- ***Good insulation and compact plan;*** external walls and ground floor insulation significantly better than the contemporary Building Regulations. Compact rectangular plans and detailing are used to avoid thermal bridges and minimise draughts.
- ***Internal planning to suit direct gain;*** main living rooms and bedrooms with the larger windows on the south side; entrance hall and kitchen (to prevent possibility of summer overheating) with smaller windows on the north side.
- ***Dense materials to absorb solar gains;*** some stud walls changed to block, and use of quarry tile floor to store solar gains and even out temperature swings.
- ***Distribution of solar and internal gains;*** a through living room and kitchen/family room allows distribution of solar and internal gains from the south to the north side of the house and also makes it possible to increase daylight where the north-facing windows are small.

Benefits of the design

The use of these simple cost-effective measures has resulted in a low energy and sunny house design. Solar gains are estimated to contribute 32% of the useful heat input.

The layout of the family room, with the kitchen sited at the north end of the room, has some advantages (see figure 2b). With high levels of insulation small kitchens can overheat, particularly if sited on the southern side of the house. The kitchen/family room solution helps dissipate incidental gains from cooking and other appliances over a wider area. This is, in effect, a farmhouse kitchen, which is popular in this market in Northern Ireland.

FINAL DESIGN

The large living room which unites both south- and north-facing naturally lit zones is an effective method of distributing solar gains. House plans with dining rooms or studies isolated on the north side of the house are not so successful in exploiting solar gain.

The uninterrupted distribution of solar gains from the southern side of the house to the north by the use of a single through-room has applications in other plan types. For example, with combined living/dining rooms the frontage of the house does not need to be so wide.

Heating system

The house uses an oil-fired boiler and radiators fitted with thermostatic radiator valves which enable the heating system to respond quickly to solar gains and thus prevent energy wastage. There is an open fire in the living room which was added for marketing reasons at the client's insistence. But solid fuel heating systems are relatively inefficient, especially in houses with a high proportion of unpredictable solar gains, and are therefore inappropriate to a passive solar design. As the fireplace was included for decorative purposes, the performance modelling of the passive design and of the reference was based on the oil-fired system only.

COMPARISON WITH A 'NON-SOLAR' DESIGN

The energy performance of the new passive solar design was compared to a 'reference', a conventional house of equivalent size and accommodation insulated to the same standard as the new design (see figure 3). The comparison was made using a modelling programme called SERI-RES. The results predicted that the annual auxiliary heating (oil) needed for the design would be 8861 kWh/yr or 64.1 kWh/m^2. This is 6% less energy than is needed for the reference. This advantage would have been increased to 11% if, instead of being outside the main envelope in the utility room, the boiler was placed in the kitchen where the boiler losses could have contributed to the internal gains.

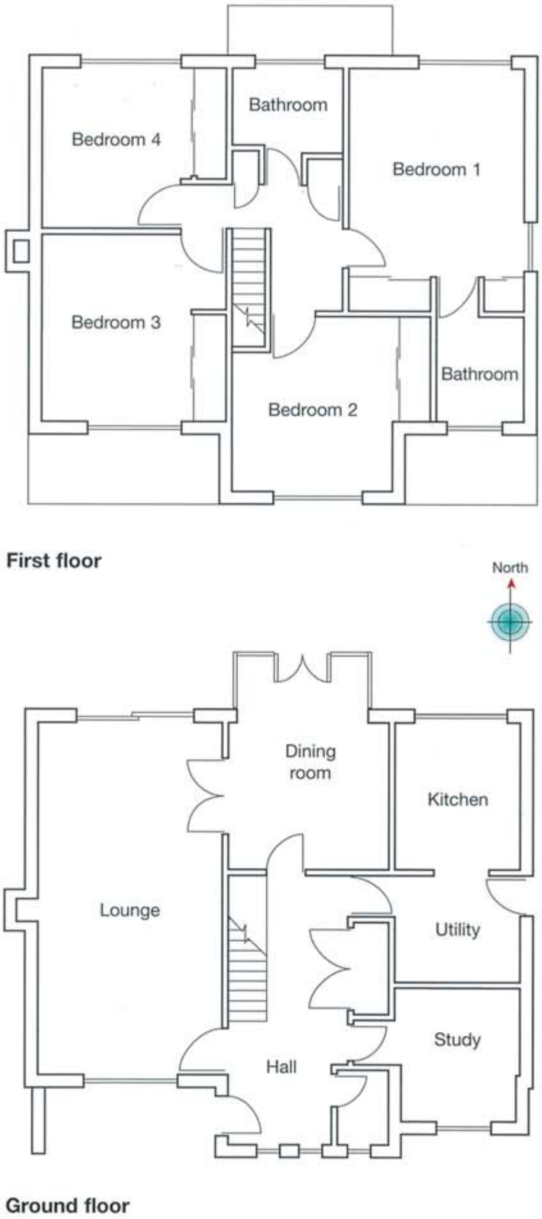


Figure 3 Plans of the 'reference' house

COMPARISON WITH A 'NON-SOLAR' DESIGN

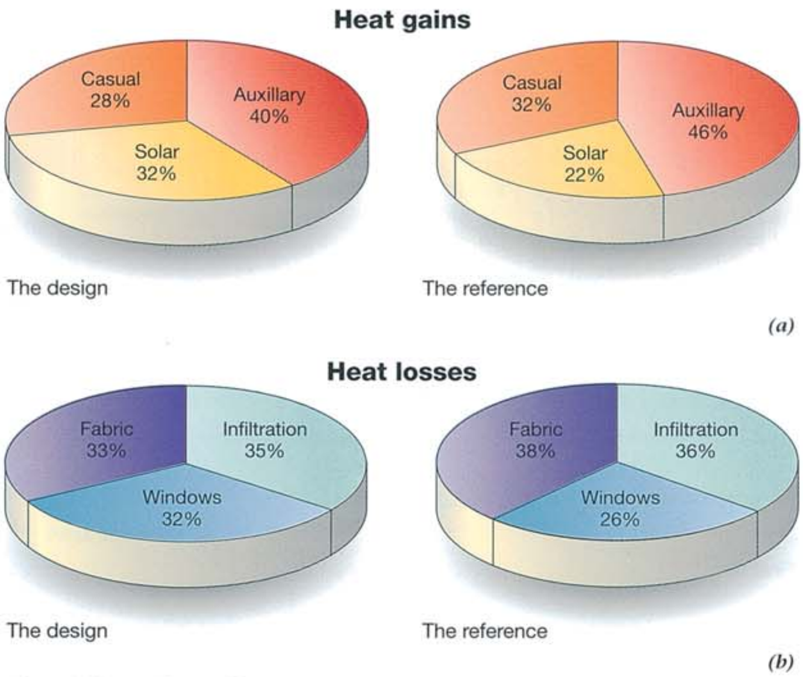


Figure 4 Heat gains and losses

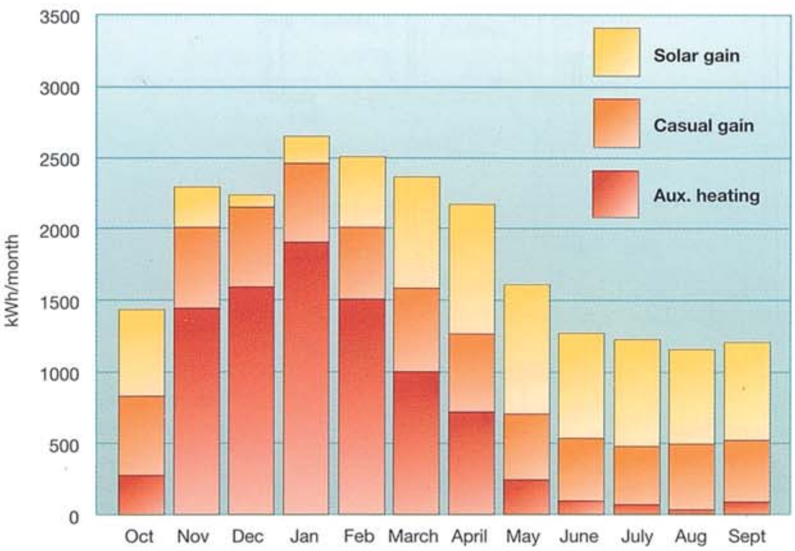


Figure 5 Predicted useful monthly gains for the design*

*Gains are considered 'useful' if they help to raise the temperature to 21°C

There are two main reasons for the better performance of the passive solar design. About half of the advantage derives from the more compact rectangular plan of the design, and half from the design's greater south biased glass area – 76% of the design's glazing faces south compared with only 45% for the reference. The useful solar gains through the design's windows (6896 kWh/yr) are therefore substantially greater than those for the reference (4655 kWh/yr) (figure 4a) and this more than compensates for the greater window losses from the design (6975 kWh/yr) compared to the reference (5521 kWh/yr) (figure 4b). The window sizes for the passive solar design are close to the optimum for achieving a positive balance between solar gains coming in and heat losses going out.

Control of heating

In both the passive solar design and the reference it was predicted that a continuous heating schedule, as opposed to an intermittent one, increased energy demand by less than 10%, because good insulation reduces heat losses between heating periods. But the setting of the heating thermostat (set at 20°C for the modelling), has a significant effect on both houses. For example, the annual heating demand of the passive solar design increases by an average of 1300 kWh/yr for every 1°C increase in setpoint temperature.

Cost

The estimated cost of the passive solar design is very similar to that of the reference. The walls and roof of the new design are cheaper because of its compact shape, but its balcony, which is a useful feature but has no energy-related function, is a notable extra cost.

The cost estimate (1992) for the passive solar design was £42 246 or £306/m² and that of the reference £304/m².

MAIN LESSONS FROM THIS STUDY

MAIN LESSONS FROM THIS STUDY

The architects had no special experience of passive solar design prior to working on this study. This was demonstrated in their initial design which, though correct strategically, was over-elaborate in execution, and added extra expense. For example, they used a conservatory because this is generally thought to be a cost-effective energy saving measure – they hardly ever are, either in cost or energy, because of the tendency for people to heat them.

The study shows that passive design principles are not complicated and can be quickly learned, and that simple passive measures, such as consideration of appropriate orientation linked to internal layout and optimum window disposition, are most likely to result in successful cost-effective passive solar house designs.

Project data

	U (W/m^2 °C)	A (m^2)	%
Total floor area		138	
Roof	0.26		
Ground floor	0.30	69	
External walls	0.31	130	
Windows – (DG)	0.29	29	100
south-facing		22	76
Cost (1992)			
Design	£42 246	£306/m^2	GFA
Reference	£41 919	£304/m^2	GFA
Density	9.3 houses per hectare		

Weather data for Aldergrove in Northern Ireland and an eight-month heating season from October and May were used.

Conclusions from the House Design Studies programme

The following lessons have been learned from the DTI's series of House Design Studies, of which this study is but one.

- Solar energy is freely available and non-polluting, but it needs to be integrated with other design aspects, especially heating controls, to be fully exploited.
- Attention to site layout and window design can reduce space heating demand by up to 10% compared with an average new house.
- Houses should be positioned on site to minimise the amount by which they are overshadowed. A change in the overshading angle (skyline) from 5° to 15° can typically increase the heating demand by about 5%.
- Houses should be oriented so that their main glazed elevation is ideally within 30°, and no more than 45°, of south. A SW or SE orientation will increase the heating demand by up to about 4% and W or E orientation by up to 11%.
- Use a well-insulated and reasonably compact plan to minimise the exposed surface area.
- Locate the rooms that need the higher temperatures and which are most frequently used, eg living-room and bedrooms, on the south side, and place other rooms on the north side.
- Passive solar houses do not require especially large south-facing windows. It is more important to ensure that north-facing windows are reduced in size, which may mean reconsidering the room layout.
- South-facing glazing should be at least double glazed or better to produce savings, especially further north in the UK. The same design in Scotland is likely to have a heating demand up to 15% to 20% more than in the south of England.
- Use fast-response and high-efficiency heating systems, with thermostatic radiator valves, especially in south-facing rooms.

FURTHER READING

FURTHER INFORMATION

Architectural Association School of Architecture. Solar Energy and Housing Design. Volume 1 (Principles, Objectives) ISBN 1 870890 36 1 Volume 2 (Examples) ISBN 1 870890 37 X. AA Publications, London, 1994

Building Research Establishment. Site layout planning for daylight and sunlight. *BR* 209. Garston, BRE, 1991 (available from CRC Publications. Tel 0171 505 6622)

DOE ENERGY EFFICIENCY BEST PRACTICE PROGRAMME DOCUMENTS

The following Best Practice programme publications are available from BRECSU Enquiries Bureau. Contact details are given below.

Good Practice Guide

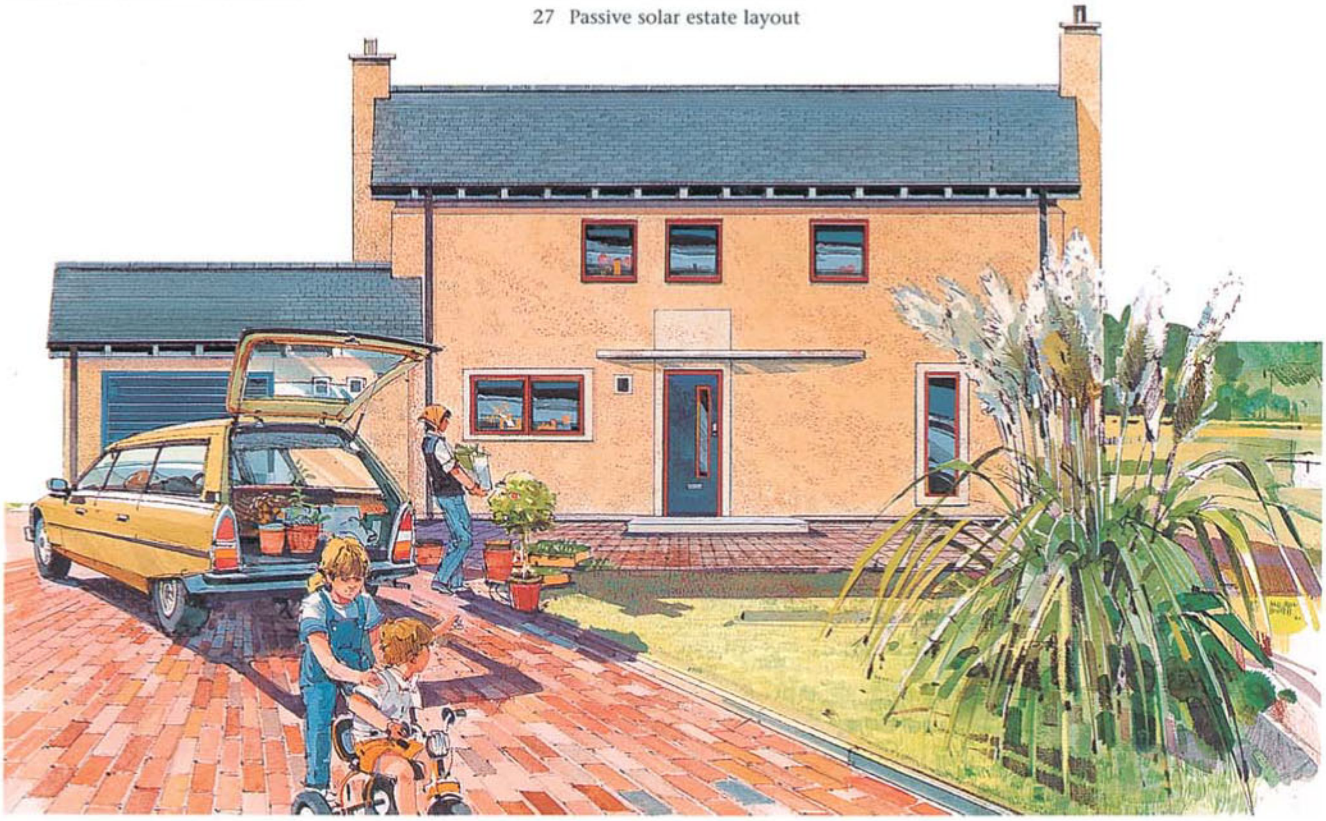
73 Energy efficient house design - exploiting solar energy

General Information Leaflet

22 Passive solar house designs - Barratt Study

General Information Report

27 Passive solar estate layout



Energy Efficiency Best Practice in Housing

Tel: 0845 120 7799
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